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In view of the great uncertainty that exists as to the true cause of pellagra, it may not be amiss to suggest that pending the final solution of this problem it may be well to attempt to prevent the disease by improving the dietary of those among whom it seems most prevalent. In this direction I would urge the reduction in cereals, vegetables, and canned foods that enter to so large an extent into the dietary of many of the people in the South and an increase in the fresh animal food component, such as fresh meats, eggs, and milk.

It may be of interest to add that intensive studies along the lines so strongly suggested by the observations above considered are being prosecuted by several groups of workers of the United States Public Health Service.

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### WHAT IS A SAFE DRINKING WATER?<sup>1</sup>

By ALLAN J. McLAUGHLIN, Surgeon, United States Public Health Service, Chief Sanitary Expert and Director of Field Work, International Joint Commission.

Cities using sewage-polluted water without purification invariably have very high typhoid-fever rates. The installation of a filtration plant to purify the polluted water supply almost without exception effects a prompt and marked reduction in the typhoid-fever rates. This reduction is usually so great that municipal officials are satisfied that their water supply is perfect when in reality there is still something to be desired. When a city with a typhoid-fever death rate persistently above 100 per 100,000 population has a reduction coincident with the installation of a filtration plant to a rate between 20 and 30, there is good ground for general rejoicing because of the undeniable saving of human lives. Nevertheless the raw water may be of such a character that an unreasonable burden is imposed on the filtration plant, and under such circumstances, in spite of fair efficiency, the plant delivers an effluent which is unsafe at times.

With the general sanitary conditions which pertain in American cities and a safe public water supply there is no valid excuse for typhoid death rates above 20 per 100,000 population per annum. There is excellent evidence to show that if all the water-borne typhoid were eliminated in northern cities the death rate for typhoid fever would be less than 10. As a matter of fact, there is a group of American cities which is fast approaching European cities in the matter of low typhoid-fever rates. These are the cities which have gone farthest in making their water supplies safe; and while their yearly typhoid death rates are not always expressed in a single figure, their rates are usually below 12. In these cities, with safe water supplies,

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<sup>1</sup> This paper was submitted for the information of the International Joint Commission at the hearing held in New York City May 26, 1914.

the general sanitary conditions, exclusive of water supply, are not conspicuously better and in some instances are very much worse than those found in cities with polluted water supplies and high typhoid-fever rates.

There is a large group of cities in which, following the substitution of a filtered for an untreated surface water supply, the rates have been greatly reduced, but still remain too high. These cities should not be satisfied with typhoid-fever death rates of from 15 to 30. It behooves them to make a searching investigation to determine whether the raw water imposes an unreasonable burden on their filtration plant or whether their plant is efficiently operated and delivering a safe water at all times. This brings us to the question:

### What is Safe Drinking Water?

In order to say that a drinking water is hygienically safe one must be assured that it contains no pathogenic bacteria. The efficiency of water purification plants varies from day to day and from hour to hour, and an opinion upon the absolute safety of a given water supply can not be rendered unless many bacteriologic analyses, made at short intervals during each 24 hours, show an absence of the *Bacillus coli*. While an absolute dictum is thus most difficult to secure, it is not difficult to determine, by daily bacteriologic analyses, that a water does or does not give a reasonable index of safety. Instead of attempting to find the germs of typhoid fever, Asiatic cholera, and dysentery in water, we accept the presence of the *Bacillus coli* as an index of pollution with sewage, for the reason that the chances of finding the *Bacillus coli* are very much better than the chances of finding the specific germs in the small quantity of water examined.

When we consider the grossly polluted water supplies used by many of our large cities until recent years, we must admit that even if the present effluents from filter plants do not show constant absence of *Bacillus coli*, they must be classed as reasonably safe, or relatively safe water.

In order to secure statistics from some of our largest filtration and purification plants a circular letter was sent out to about 40 cities.

About 15 responded, and in most instances the statistics covered at least one year. The list included mechanical, or rapid sand, filtration, slow sand filtration, precipitation and disinfection, and disinfection alone.

TABLE 1.—*Showing average number of Bacillus coli per 100 c. c. in both raw water and filtered or treated water of certain cities.*

| City.                   | Number of samples. | Type of filtration.                | Average number of <i>B. coli</i> per 100 c. c. |                            |
|-------------------------|--------------------|------------------------------------|--|----------------------------|
|                         |                    |                                    | Raw water.                                     | Filtered or treated water. |
| Toledo, Ohio.....       | 342                | Mechanical filtration.....         | 804  | 0.02                       |
| Minneapolis, Minn.....  | 418                | do.....                            | 75   | .1                         |
| Grand Rapids, Mich..... | 365                | do.....                            | 92   | .3                         |
| Cincinnati, Ohio.....   | 240                | do.....                            | 1,175  | 1.4                        |
| Birmingham, Ala.....    | 205                | do.....                            | 196  | 1.0                        |
| Binghamton, N. Y.....   | 174                | do.....                            | 400  | 0.2                        |
| Columbus, Ohio.....     | 420                | do.....                            | 59   | 1.2                        |
| Washington, D. C.....   | 365                | do.....                            | 606  | 1.3                        |
| Providence, R. I.....   | 348                | Slow sand.....                     | 2,501  | 1.4                        |
| Reading, Pa.....        | 600                | do.....                            | 732  | 4.3                        |
| Baltimore, Md.....      | 138                | do.....                            | 68   | 5.8                        |
| Richmond, Va.....       | 306                | Alum and calcium hypochlorite..... | 1,349  | 2.5                        |
|                         | 237                | do.....                            | 460  | 8.0                        |

Some of the results are of special interest and the statistics for these cities are presented by months.

#### Toledo, Ohio.

The Toledo plant is of the mechanical gravity type. Calcium hypochlorite is applied to the raw water before sedimentation in quantities of 15 to 30 pounds per million gallons. Then aluminum sulphate is used as a coagulant.

Table 2 shows the results by months in Toledo. The Toledo plant by the use of heroic doses of hypochlorite is able to convert a bad raw water into a safe effluent, but in spite of this fact the necessity for constant efficiency in treating such a raw water every hour in every day from January to June places an unreasonable responsibility on the plant. From June to October a fair raw water is furnished. In November and December the *Bacillus coli* per 100 c. c. in the raw water was again too high.

TABLE 2.—*Showing, by months, the results of treatment of the Toledo water supply.*

| Month.                             | Number<br>of days<br>samples. | Average number <i>B. coli</i> per 100 c. c. |                    |
|------------------------------------|-------------------------------|---|--------------------|
|                                    |                               | Raw water.                                  | Filtered<br>water. |
| 1913.                              |                               |   |                    |
| January.....                       | 25                            | 1,848                                       | 0                  |
| February.....                      | 26                            | 145   | 0                  |
| March.....                         | 26                            | 2,238                                       | .3                 |
| April.....                         | 30                            | 1,105                                       | 0                  |
| May.....                           | 29                            | 1,270                                       | 0                  |
| June.....                          | 28                            | 67  | 0                  |
| July.....                          | 27                            | 300   | 0                  |
| August.....                        | 11                            | 600   | 0                  |
| September.....                     | 30                            | 280   | 0                  |
| October.....                       | 29                            | 286   | 0                  |
| November.....                      | 27                            | 766   | 0                  |
| December.....                      | 23                            | 530   | 0                  |
| 1914.                              |                               |   |                    |
| March.....                         | 31                            | 1,000                                       | 0                  |
| January, 1913, to March, 1914..... | 342                           | 804   | 0.029              |

**Minneapolis, Minn.**

Excellent results are also obtained in Minneapolis by a mechanical or rapid sand filtration plant. Minneapolis differs from Toledo in that the hypochlorite is applied to the filtered water, and not to the raw water, in quantities of 3-10 to 4-10 parts per million available chlorine per million gallons. The raw water at Minneapolis is very much better than that of Toledo.

TABLE 3.—*Showing, by months, average number of Bacillus coli per 100 c. c. in both raw and filtered water in Minneapolis, Minn.*

| Month.                              | Number<br>of days<br>samples. | Average number <i>B. coli</i> per 100 c. c. |                    |
|-------------------------------------|-------------------------------|---|--------------------|
|                                     |                               | Raw water.                                  | Filtered<br>water. |
| 1913.                               |                               |   |                    |
| February.....                       | 26                            | 23  | 0.7                |
| March.....                          | 31                            | 39  | 0                  |
| April.....                          | 30                            | 8   | .3                 |
| May.....                            | 29                            | 44  | 0                  |
| June.....                           | 30                            | 25  | 0                  |
| July.....                           | 31                            | 73  | 0                  |
| August.....                         | 31                            | 85  | .6                 |
| September.....                      | 30                            | 79  | 0                  |
| October.....                        | 31                            | 53  | 0                  |
| November.....                       | 30                            | 85  | 0                  |
| December.....                       | 30                            | 100   | 0                  |
| 1914.                               |                               |   |                    |
| January.....                        | 30                            | 100   | 0                  |
| February.....                       | 28                            | 90  | .3                 |
| March.....                          | 31                            | 242   | .6                 |
| February, 1913, to March, 1914..... | 418                           | 75  | .19                |

## Cincinnati, Ohio.

The Cincinnati plant utilizes plain sedimentation followed by coagulation and mechanical filtration. Sulphate of iron and caustic lime are used, the latter to assist the action of the iron sulphate and not for softening purposes. Calcium hypochlorite is added to the filtered water for about five months in the year. About one pound is used to each million gallons of water. Hypochlorite is used during January, February, March, April, and May, which covers the period of muddy water and high bacterial counts.

TABLE 4.—Showing, by months, average number of *Bacillus coli* per 100 c. c. in both raw and treated water in Cincinnati.

| Month.                               | Number of days samples. | Average number <i>B. coli</i> per 100 c. c. |                 |              |
|--------------------------------------|-------------------------|---|-----------------|--------------|
|                                      |                         | Raw water.                                  | Filtered water. |              |
|                                      |                         |   | Without "hypo." | With "hypo." |
| 1913.                                |                         |   |                 |              |
| September.....                       | 28                      | 964   | 2.1             | .....        |
| October.....                         | 31                      | 358   | 1.5             | .....        |
| November.....                        | 30                      | 1,990                                       | 2.7             | .....        |
| December.....                        | 31                      | 1,841                                       | 3.0             | .....        |
| 1914.                                |                         |   |                 |              |
| January.....                         | 31                      | 1,232                                       | 9.1             | 0.6          |
| February.....                        | 28                      | 1,260                                       | 3.5             | 1.2          |
| March.....                           | 31                      | 825   | 2.4             | .06          |
| April.....                           | 30                      | 933   | 20.0            | .4           |
| September, 1913, to April, 1914..... | 240                     | 1,175                                       | 5.6             | 1.4          |

The results are very interesting. A bad, raw water which threatens to overtax the purifying capacity of the filters is successfully handled by the use of hypochlorite as an auxiliary. The results shown in Table 4 indicate that in January, February, March, and especially April, 1914, the plant without the aid of calcium hypochlorite was unable to successfully cope with the bad, raw water. With the aid of "hypo" a good effluent was secured.

## Columbus, Ohio.

At the mechanical filtration plant of Columbus, Ohio, lime, soda ash, and aluminum sulphate are used. Hypochlorite is occasionally used applied to the settled water before filtration. Table 5 gives results by months for the year 1913. With a bad, raw water excellent results are obtained. Mr. Hoover, the chemist in charge, attributes these results to the free use of lime. This seems probable, as very little hypochlorite is used.

TABLE 5.—Showing, by months, the average number of *Bacillus coli* per 100 c. c. in both raw and filtered water in Columbus, Ohio.

| Month.                   | Number<br>of days<br>samples. | Average number <i>B. coli</i> per 100 c. c. |                 |
|--------------------------|-------------------------------|---|-----------------|
|                          |                               | Raw water.                                  | Filtered water. |
| 1913.                    |                               |   |                 |
| January.....             | 31                            | 3,462                                       | 1.6             |
| February.....            | 28                            | 272   | 1.0             |
| March.....               | 31                            | 782   | 0               |
| April.....               | 30                            | 931   | 2.3             |
| May.....                 | 31                            | 196   | 1.9             |
| June.....                | 30                            | 283   | 0               |
| July.....                | 31                            | 378   | 5.1             |
| August.....              | 31                            | 277   | .6              |
| September.....           | 30                            | 294   | .3              |
| October.....             | 31                            | 131   | 1.2             |
| November.....            | 30                            | 178   | 1.3             |
| December.....            | 31                            | 33  | .3              |
| January to December..... | 365                           | 606   | 1.3             |

## Washington, D. C.

Washington, D. C., has a slow sand filtration plant. There is large reservoir capacity, and some alum is used in times of high turbidity. No hypochlorite or chlorine is used at any time. The general average for the Washington plant for 348 samples shows 1.4 *Bacillus coli* per 100 c. c., which must be classed as a very good effluent. A close study of the results for individual months shows that there is great fluctuation in the character of the raw water. There was a very bad raw water in January, 1913, and April, 1913, and the results show that this unusual burden was probably too much for the purifying capacity of the plant. Table 5 shows the results of filtration in Washington, D. C., by months.

TABLE 6.—Showing by months the average number of *Bacillus coli* per 100 c. c. in both raw and filtered water in Washington, D. C.

| Month.                                | Number<br>of days<br>samples. | Average number <i>B. coli</i> per 100 c. c. |                    |
|---------------------------------------|-------------------------------|---|--------------------|
|                                       |                               | Raw water.                                  | Filtered<br>water. |
| 1913.                                 |                               |   |                    |
| January.....                          | 25                            | 4,582                                       | 7.4                |
| February.....                         | 23                            | 502   | 1.0                |
| March.....                            | 25                            | 2,871                                       | .5                 |
| April.....                            | 26                            | 20,910                                      | 4.1                |
| May.....                              | 26                            | 661   | 0                  |
| June.....                             | 25                            | 910   | 0                  |
| July.....                             | 26                            | 5   | 0                  |
| August.....                           | 24                            | 88  | 0                  |
| September.....                        | 25                            | 412   | .5                 |
| October.....                          | 27                            | 622   | 4.7                |
| November.....                         | 23                            | 1,167                                       | .5                 |
| December.....                         | 25                            | 538   | .5                 |
| 1914.                                 |                               |   |                    |
| January.....                          | 25                            | 640   | 0                  |
| February.....                         | 23                            | 211   | .5                 |
| January, 1913, to February, 1914..... | 348                           | 2,501                                       | 1.4                |

**Birmingham, Ala.**

The water supply for Birmingham is derived from two separate sources, as follows:

(a) Five Mile Creek, which is a stream to the north of the city, having a minimum flow of four and one-half million gallons, with a watershed area of 16.1 square miles and a population density of 31.9 persons to the square mile. Five million gallons daily are supplied from this stream except during the dryest seasons. The waters of Five Mile Creek are diverted at a point 6 miles from the city and brought by gravity through a closed conduit to the North Birmingham purification plant, which consists of sedimentation basins and rapid sand filters of 5,000,000 gallons nominal capacity and disinfection by hypochlorite.

(b) Cahaba River. The watersheds of Cahaba River lie to the east of Birmingham. The west prong, or Big Cahaba, furnishes the supply, except when its minimum flow is less than the daily pumpage, in which case the East Cahaba is drawn upon by means of a small diversion dam below the junction of the two rivers. To supplement the dry weather flow, a dam has been built on the East Fork, or Little Cahaba, and a large impounding reservoir of 1,250,000,000 gallons created, known as Lake Purdy. The total watershed area is 205 square miles. The area above Lake Purdy is 49.7 square miles. The density of population on the entire shed is estimated at about 20 per square mile.

The pumping station on the Big Cahaba, 2 miles above the diversion dam at the junction of the two forks, forces the water to a purification plant on Shades Mountain. The purification plant consists of two large sedimentation reservoirs, holding 118,000,000 and 28,000,000 gallons, from which the water flows by gravity through a rapid sand filtration plant, having a present nominal capacity of 19,000,000 gallons daily, with eight additional million-gallon units under construction. The filters discharge into a clear-water basin of 3,000,000 gallons capacity, from which the water flows by gravity to the city, a distance of 4 miles.

TABLE 7.—*Showing, by months, the average number of Bacillus coli per 100 c. c. in both raw and filtered water in the Cahaba and North Birmingham plants, Birmingham, Ala.*

**CAHABA PLANT.**

| Season.              | Number of days samples. | Average <i>B. coli</i> per 100 c. c. |                 | Remarks.         |
|----------------------|-------------------------|--------------------------------------|-----------------|------------------|
|                      |                         | Raw water.                           | Filtered water. |                  |
| 1913.                |                         |                                      |                 |                  |
| Jan. 1-Feb. 28.....  | 35                      | —305                                 | 0.28            | No chlorination. |
| Mar. 1-Apr. 10.....  | 35                      | —305                                 | .56             | Do.              |
| Apr. 11-May 21.....  | 35                      | — 87                                 | .00             | Do.              |
| May 22-July 21.....  | 35                      | —204                                 | 2.28            | Do.              |
| July 23-Oct. 20..... | 35                      | —112                                 | 1.4             | Do.              |
| Oct. 22-Nov. 28..... | 16                      | — 23                                 | 0               | Do.              |
| Dec. 1-Dec. 30.....  | 14                      | —323                                 | 4.2             | Do.              |
| Jan. 1-Dec. 31.....  | 205                     | —196                                 | 1.0             |                  |

TABLE 7.—Showing, by months, the average number of *Bacillus coli* per 100 c. c. in both raw and filtered water in the Cahaba and North Birmingham plants, Birmingham, Ala.—Continued.

## NORTH BIRMINGHAM PLANT.

| Season.               | Number of days samples. | Average <i>B. coli</i> per 100 c. c. |                 | Remarks.           |
|-----------------------|-------------------------|--------------------------------------|-----------------|--------------------|
|                       |                         | Raw water.                           | Filtered water. |                    |
| 1913.                 |                         |                                      |                 |                    |
| Jan. 1-Feb. 6.....    | 31                      | 700                                  | 0.3             | With chlorination. |
| June 9-July 25.....   | 33                      | 800                                  | .6              | Do.                |
| July 28-Sept. 12..... | 35                      | 1,337                                | .3              | Do.                |
| Sept. 15-Nov. 3.....  | 34                      | 288                                  | 0               | Do.                |
| Nov. 4-Dec. 31.....   | 41                      | 240                                  | 0               | Do.                |
| Jan. 1-Dec. 31.....   | 174                     | 400                                  | .2              |                    |

The two Birmingham plants furnish very interesting data on the value of hypochlorite as an aid in handling a bad raw water. The Cahaba plant uses no hypochlorite. In December, 1913, raw water with an average of 323 *Bacillus coli* per 100 c. c. seemed to overtax the purifying capacity of the plant. A load of 204 *Bacillus coli* per 100 c. c. in June and July seemed to be about the limit that the plant could care for, although in the period from January 1 to April 10, an average of 305 in the raw water was reduced to less than 1 *Bacillus coli* per 100 c. c. in the effluent. The North Birmingham plant had a worse raw water to deal with. This plant uses hypochlorite as an adjuvant. The average for raw water of 700, 800, and 1,337 *Bacillus coli* per 100 c. c. was reduced to less than 1 *Bacillus coli* per 100 c. c. in the effluent. From September to December with a fair raw water averaging 240 and 288 *Bacillus coli* per 100 c. c. a perfect result was obtained with entire absence of *Bacillus coli* in the 71 samples.

Following a sanitary survey of the cities and towns in the basin of the Great Lakes, the writer recommended, among other things necessary, that a standard for filtered or treated water be established which should be a minimum requirement for the prevention of the spread of water-borne disease in interstate traffic. I believe that a standard of not more than 2 *Bacillus coli* per 100 c. c. of water, taking the average of many samples by the Phelps<sup>1</sup> method, should be adopted.

Allowing a sufficient margin of safety, filter plants with a good raw water should produce effluents of less than 2 *Bacillus coli* per 100 c. c., and it is the opinion of the writer that a modern water purification plant which delivers an effluent which has more than 2 *Bacillus coli* per 100 c. c. is either inefficiently operated or is dealing with a raw water which imposes an unreasonable burden upon the

<sup>1</sup> Phelps, Earle B. A method for calculating the number of *B. coli* from the results of dilution tests. Reports and Papers of the American Public Health Assn., vol. 33, 1907, pt. 2, pp. 9-13.

plant. Accepting tentatively the standard of less than 2 *Bacillus coli* per 100 c. c. as a good drinking water, although perhaps not an ideal drinking water or a safe drinking water at all times, the results indicate that this standard is attained by both rapid sand and slow sand plants, even with a very bad raw water. Cincinnati and Washington, D. C., are good examples of each type. Close examination of the daily records at Washington and Cincinnati show that while this excellent average is attained for the year, there are periods when the capacity for purification seems to be overtaxed by the very bad raw water. At Cincinnati the use of hypochlorite seems to compensate for the deficiency in purification by the standard process, but in Washington the excellent general average of 1.4 is attained only by the almost perfect purification effected during periods when the raw water is fairly good.

There is a strong tendency in America to accept any raw water, however bad, as a source of supply for a municipal filtration plant. This often imposes an unreasonable burden and responsibility upon the water purification plant. Now, filter plants are not infallible. They are mechanisms which must be properly constructed and efficiently operated under careful bacteriologic control in order to secure a safe effluent. They are operated by human agency and subject to the results of human error. It is true that properly constructed and efficiently operated filter plants can produce safe water from a very bad raw water, especially by the use of hypochlorite or liquid chlorine as an adjuvant. The responsibility of effecting such purification every hour of every day in the year is unreasonable and unfair. Many plants are now struggling with a raw water of such a character that a safe effluent is obtained only at the price of eternal vigilance, perfect operation every day in the year, and the free use of auxiliary chemicals. The raw water demanding such extraordinary treatment is like a sword of Damocles constantly threatening disaster. There is no margin of safety under such conditions.

I believe that a sufficient margin of safety should be given to all filter plants by reducing the pollution of the raw water to a point where it would not impose an unreasonable burden or responsibility upon the plant. I believe that in reckoning the bacterial purifying capacities of filtration plants hypochlorite or liquid chlorine should not be considered, but that a raw water should be furnished of such a character that the plant could turn out consistently a safe effluent without the aid of chlorine. This would reserve the chlorination as an additional margin of safety for use in extraordinary fluctuations of the raw water or during accidents to the plant or interruptions in its ordinary efficiency.